tank by opening that tank's ballast water inlet valve. The residual fuel in the expansion tank from refueling will be forced into the FOB tank until the expansion tank is solidly filled with ballast water. Ballast water will then be supplied into the FOB tank under "suction."

As a service tank reaches the 50% level, suction is shifted to the other service tank and the standby service tank is filled from the fuel oil purifier collecting tank by way of a fuel oil if needed. As the FOB is used, a small amount of ballast water will overflow into the fuel oil collecting tank. This small amount of ballast water can be stripped into the expansion tank, maintaining good fuel in the collecting tank. The vertical separation of the fuel oil inlet from the FOB tanks (low) and the fuel oil discharge to the purifier (high, near tank top) will provide a high degree of fuel quality.

The sea water compensating system:

▶ Permits the fueling and defueling of all fuel tanks

▶ Permits the transfer of fuel from each FOB tank to the fuel oil collecting tank

▶ Allows the transfer of fuel to service tanks through a purifier

▶ Provides for maximum stability as fuel is replaced by sea water (ballast)

▶ Limits the pressure differential between tank static head pressure and salt water supply.

The fuel oil collecting tank:

▶ Serves as a settling tank for fuel oil (any water entering this tank is allowed to settle out)

▶ Prevents water from expended fuel oil tanks still on "suction" from being transferred to the service tank (through a purifier)

▶ Is fitted with a low suction (drain line) to allow a stripping pump to draw off water and discharge to the expansion tank.

The expansion tank:

▶ Serves as a reservoir for fuel which may flow if expansion occurs because of temperature variations

▶ Serves as a buffer or "overflow" tank during fueling

▶ Serves as a receptacle for discharge of stripping conducted on the fuel oil collecting tank

▶ Forces fuel back into an FOB tank when placed on line for supply to the fuel oil collecting tank.

This modification to a conventional ballast system:

▶ Maintains stability through continuous supply of sea water to each FOB tank as fuel is used

▶ Ensures maximum protection against war damage by maintaining a liquid layer between hull and adjacent spaces

▶ Limits the possibility of off-center flooding which would be experienced if the tank was holed or opened to the sea

▶ Minimizes/eliminates the presence of fuel vapors which would be present in an unballasted tank

▶ Provides a more efficient means of "stripping" which will result in more fuel being reclaimed

▶ Reduces the number of man-hours required to monitor and strip "conventional" sea water-ballasted tanks

▶ Reduces the possibility of polluting the environment with fuel oil because of the addition of the expansion tank

The second option would be less extensive. It would require a minor modification to the existing fuel oil transfer system. The installation of an oily waste water separator/purifier in the transfer system would allow ship's company to ensure that fuel remains uncontaminated with a greater degree of confidence than that provided by existing stripping systems. This would reduce the degree of difficulty associated with current stripping systems. (Since our stripping suctions are only inches below our fuel suctions, any condensation or settling of water in a tank can easily show up in the pre-transfer sample, requiring further stripping.)

In addition, preservation of all fuel tanks would be required. The coating of fuel tanks is necessary to reduce corrosion of the tank walls. If corrosion can be minimized and an increased number of drainage holes are provided in the longitudinals, the pocketing of ballast water in those longitudinals can be eliminated. Given adequate material condition of the tank systems and an efficient means of fuel/water separation, routine ballasting can be accomplished.

Of these two options, the second appears to require less funding. The advantages offered by either of these options, however, greatly outweigh their disadvantages. While the expenditures required are tremendous, the potential savings in lives and material in wartime should more than balance the scales.

Lieutenant Commander Hammond graduated from the U. S. Naval Academy in 1972 with a B. S. degree in oceanography and later earned a Master of Marine Affairs degree at the University of Rhode Island. Currently, he is an engineering instructor at the Surface Warfare Officers School in Newport, Rhode Island.

The Marines: Taking the Heat

By Paul O. Davis and Commander Robert J. Biersner, Medical Service Corps, U. S. Navy

During the middle of July 1980, a team of exercise physiologists spent four days with a regular Marine Corps battalion at the Combined Arms Combat Center in Twentynine Palms, California, to gather information on the characteristics of physical tasks performed by marines in a desert combat environment. Each member of the team was assigned to observe two Marine Corps infantry riflemen.

Equipment: The uniform worn for the exercise was the current issue jungle utility made of a cotton-poplin camouflage material. A desert camouflage material is being developed that will blend with desert surroundings better than this jungle design. Movement over the rough terrain accelerates uniform wear. Most of the uniforms had tears in the knees, elbows, and seats. Although the trousers are rip-stop, they did not provide sufficient protection against the sharp, jagged rocks of the desert terrain. In addition, the dark-colored uniform is hot. While the sleeves can be rolled up easily, this exposes the skin to the sun. Because marines must pay for their own utilities, they were concerned about frequent replacement. The newly designed uniform should greatly aid in reducing these problems.

The footwear issue was the black combat boot, though some wore the canvas-sided jungle boot. The black boot did not have an adequate sole for traction on the fine rocks of the desert terrain, nor did it allow for proper ventilation of the feet; the leather became soaked with perspiration. There is a

The Gamma-goat is one of the more reliable forms of transportation over desert terrain; the flat, open valleys are often pocked with gullies and washes. The marine, below, carries the typical combat load, which under actual combat conditions would probably weigh 45 pounds.

PAUL O. DAVIS

new prototype combat boot that has a lugged sole and is made of unfinished leather, a characteristic that will presumably improve ventilation. However, this prototype boot failed acceptance tests largely because its durability did not meet performance requirements.

Other equipment included the all-purpose lightweight carrying equipment (ALICE) pack, cartridge belt, suspenders, canteens, and personal protection equipment. The ALICE pack was adequate for the small amount of equipment carried on this operation. There were large discrepancies in the amount of equipment brought to the field; the officers did not appear to be too concerned about which items of personal gear the marines carried. Many marines carried a minimum load, even discarding sleeping bags and personal hygiene kits. Their attitude was one of "grubbing it out" for the short (four-day) period involved. Pack weight ranged from 12 to 45 pounds. Under actual combat conditions, the maximal load of 45 pounds would most likely be carried.

This battalion spends approximately half of the year in the field. Therefore, the men were accustomed to being without amenities; most felt only extended combat would warrant bringing the full issue of equipment.

The body armor is an uncomfortable piece of gear, weighing about 12 pounds in the large size, that significantly reduces ventilation. Since the marines used live ammunition during the entire exercise, everyone was obliged to wear this armor and a helmet. The armor is being redesigned in a lighter, more flexible Kevlar material. Wearing the gas masks in temperatures of 117°F is unbearable. The wearer drowns in perspiration. Under these conditions, respiration is greatly restricted; heavy work is impossible.

No hearing protection was available except during the ride to the base. Riding in helicopters and firing weapons are two activities in which noise far exceeds recommended maximum safe limits. The report from an M-16 firing live ammunition is deafening, and riding in the CH-53 helicopter is beyond the pain threshold. Having been exposed to this problem before, some of our team members brought their own ear plugs.

Shelter: The best protection from the intense desert sun is shade, a rare commodity at Twentynine Palms. Therefore, the poncho is vital and necessary for portable shade. The poncho liner also makes an excellent sleeping bag and should be required equipment; it is adequate for temperatures into the high 50s. Some marines elected not to carry their bags and used the poncho liner for sleeping.

Aside from its excessive weight, the standard sleeping bag was quite adequate for desert temperatures that can plummet to the low 40s at night, even during the summer months. Because desert survival gear is less elaborate than its cold-weather counterpart, the weight of the sleeping bag is not an immediate concern.

The air mattress greatly improves the quantity and quality of sleep, a factor important to combat-effectiveness. Finding a level, rock-free sleeping site is no small task; the small, jagged rocks frequently punctured the air mattress making it useless because patching supplies were nonexistent. The best form of insurance against puncture is to use fully opened C-ration boxes under the air mattress. Hopefully, the newly developed closed cell foam mat expected to be in the inventory next year will correct this problem.

Water: There is no doubt that water is a tactical weapon in the desert combat environment. One gallon of water per man per day is the minimum requirement in the desert among personnel at rest; physical activity increases this amount by as much as a multiple of five. However, it is difficult to drink water that is approximately 105°F. Such temperatures result from the dark, olive-green water containers which absorb heat when left in the sun. Green canteens and black water cans kept water at a temperature comfortable for bathing but not for drinking. A desert bag canteen available at the "day store" provided palatable water for those with sufficient foresight to make the purchase. This amazing, woven-flax bag maintains the contents 20° below ambient temperature through evaporative cooling. This equipment should be issued to all marines. However, one of the disadvantages of the desert bag is evaporative water loss. If water becomes scarce, use of the bag should probably be curtailed. Development efforts could overcome this shortcoming and may prove productive in the development of a new desert canteen.

Food: Appetite appeared to be severely reduced by the heat and C-rations. Much has been said and written about the inadequacy of "C-rats," but help is supposedly on the way in the form of meals-ready-to-eat (MREs). MREs are partly freeze-dried, easily reconstitutable with water, do not require heating, and may be eaten from the package.

Personal hygiene: Evaporative water loss, coupled with blowing dust, soon covered each marine with a layer of grime and encrusted salt. Surprisingly, nearly everyone quickly adjusted to this condition. There does not appear to be much that can be done about the problem; showering in the field is clearly out of the question because of the limited water supply.

Medical considerations: Capabilities and motivation among the corpsmen varied widely. While we observed no need for treatment of acute injuries—only a few cases of heat exhaustion and one case of heat stroke—it was apparent that some corpsmen could have been more vigilant in checking urine color for dehydration. There were some who *did* provide this type of preventive care.

Movement and transport: Photographs of the combat area are quite deceiving; flat, open valleys are pocked with gullies and washes. Movement by foot over any substantial distance is prohibitive in time and physical energy costs. Clearly, moving and fighting in this environment require mobile support. When available, helolifts are an effective method for rapidly moving troops and supplies. However, rarely was the air wing able to provide the required number of craft because of mechanical or other problems.

Trucks are a grueling form of transport, but appeared to be the most reliable. The treatment of these tactical vehicles gives one a great appreciation for the engineering that makes a "marine-proof" truck. The same is true for the Gamma-goat, an articulated diesel-powered personnel and weapons carrier.

The Amtrack is an armored amphibious personnel carrier that provides an effective form of transportation. The marines were often confined to this vehicle for a number of hours. Exhaust fumes and vapors of diesel fumes were evident, and no doubt harmful for these protracted periods of time. There were some ventilatory problems with all of these vehicles.

Recommendations: The following improvements should be made to raise the personal comfort level and, consequently, the endurance and performance of the marine infantryman:

- Deliver and store water at a palatable temperature
- Acquire and issue durable, more heat-reflectant uniforms
- Make insolite or other type of sleeping pad as standard issue
- Corpsmen and unit leaders should control and monitor carefully fluid intake
- Acquire and issue footwear more conducive to desert operations; boots should have lugged soles and be adequately ventilated, as well as wear-resistant
- Assign more qualified officers and noncommissioned officers as well as a higher proportion of leaders experienced with these combat conditions to units involved in desert combat operations; injuries and adverse health effects resulting from the officers and NCOs allowing personnel to disregard these matters should be a court-martial offense, rigorously enforced.

Dr. Davis is a member and fellow of the American College of Sports Medicine and Director of the Institute of Human Performance, a research and consulting organization specializing in the development of physical performance standards for occupations requiring high levels of physical fitness. His professional note on cold weather combat operations, "The Marines: Out in the Cold," was published in the November 1981 *Proceedings*.

Commander Biersner has done graduate work at McGill University and the California Institute of Technology. He is the Program Manager for Human Performance and Aviation Medicine, Naval Medical Research and Development Command, Bethesda, Maryland.

Operating in the I. O.

By Commander Robert E. Baier, U. S. Naval Reserve

Ten years ago, U. S. Navy ships didn't spend all that much time in the Indian Ocean. Now they do, and so do Soviet Navy ships. So, if we are to operate effectively in these distant and distinct waters, we must know the I. O.

The Indian Ocean is one of the three great navigable bodies of water in the world and is the only one on which no major power borders or has direct access. It covers one-seventh of the Earth's surface. The bottom structure, so important to subsurface operations and monitoring, is grotesquely distorted by extraordinary ridges, rifts, and ranges amounting to underwater mountain groups. Undersea avalanches of mud and silt-laden water pour over its continental shelves, with turbidity currents of great enough intensity to wreak havoc on bottom-mounted devices.

Monsoon winds combine with the unique geography of the bordering lands to produce swift and shifting surface currents in the Indian Ocean, while underwater sound propagation is subjected to complex and irregular perturbations. There are anomalously deep and shallow channels and abnormally high sound velocities.

Naval operations are also hindered by extremely high salinity and high water temperatures in the northern reaches of the Indies Sea; unusually low salinity is found on the eastern boundary. In some areas, the surface water temperature attains two distinct maximum values per year, as contrasted with the single peak noted in the Atlantic and Pacific. Continuous high relative humidities, severe rainstorms, and tropical and extratropical cyclones are other difficult factors that must be recognized. In coastal areas, extremely high temperatures and severe dust storms are common. Addi-